CE 398D

DEPARTMENTAL REPORT

Summer 1994

THE RE-UTILIZATION OF CONCRETE WASTE MATERIALS

Submitted by: KENNETH R. KRUCIAK

Submitted to: DR. R. E. KLINGNER

The University of Texas at Austin

Department of Civil Engineering

ABSTRACT

This report explores the need for re-utilization of concrete waste materials in contrast to disposal by landfilling. Potential applications for the beneficial and cost-effective re-utilization of waste concrete materials are presented. Factors affecting the feasibility of re-utilization of concrete waste materials are discussed. Reduction of construction project costs and minimization of environmental impact can be realized as the result of removing concrete waste materials from the solid waste stream.

CONTENTS

1.0 INTRODUCTION

The use of concrete as a construction material consumes mineral aggregate resources. Sand, gravel and crushed stone have become more essential to the construction industry as concrete has become the preferred structural material for many applications. The United States produces 71,000,000 tons of cement annually, and mines 756,000,000 tons of sand and gravel and 1,051,000,000 tons of stone annually (Kesler 1994). Since these are considered to be unlimited or virtually unlimited in quantity, the concern is generally not the depletion of a limited resource, but rather the long-range consequences of their production, use and disposal.

Heightened environmental awareness and greater regulation have caused and will continue to cause the costs of mining construction minerals to rise, and will negatively impact the economic viability of concrete as the premier construction material.

1.1 Why Re-utilization of Concrete Waste Materials is Important

In construction economics, geologic, environmental and economic considerations are interdependent. The cost-effectiveness of mining, producing and using a material are largely determined by the distance from where the material is found to where it is used,

by the energy consumed for production and use, and by the extent of environmental regulation compliance required.

When concrete becomes a waste material, it is better to re-utilize it in a practical manner when economically feasible, rather than to dispose of it in a landfill. Re-utilization of waste concrete materials will become increasingly important to the construction industry as the use of concrete increases, and as the quantity of concrete waste materials to be disposed of increases.

1.2 Scope

This report focuses on the need for concrete waste materials to be re-utilized in practical ways instead of being disposed of in landfills. Economic benefits for the construction industry and the environmentally positive aspects of removing concrete waste materials from the solid waste stream are discussed and presented.

1.3 Objectives

This report seeks to explore the current practices of the construction industry for the disposal of waste concrete materials, and to show reasons why the re-utilization of concrete waste materials will become increasingly preferable to disposal by landfilling.

2.0 THE STATE-OF-THE-ART IN RE-UTILIZATION OF CONCRETE WASTE MATERIALS

2.1 Current Practices in the Re-utilization of Concrete Waste Materials

Recent research efforts have been undertaken to explore the viability of using crushed concrete as aggregate in place of conventional natural aggregates in concrete mixes. Concrete made with recycled concrete as aggregate was found to require a higher water-cement ratio to prevent rapid loss of workability due to the crushed concrete aggregate being much more absorptive than natural stone aggregates (Azis and Ramaswamy 1992). The area of bond between fresh mortar and crushed concrete particles is where the compressive strength failure propagated in concrete mixes when recycled concrete was used as the aggregate for new concrete (Kim et al 1992). With varying degrees of success, many state highway departments are investigating the use of concrete waste materials, including the use of crushed concrete aggregates in asphalt pavements (Ahmed 1993). Also, recycled concrete is one material being incorporated as a portion of the subbase course in road construction (Suss 1989).

2.2 Current Examples of Re-utilization of Concrete Waste Materials

The Texas Department of Transportation (TxDOT) generally does not require specific re-utilization of concrete waste materials on highway projects as it does for asphalt pavements (R1). The choice of whether to landfill concrete waste materials or re-utilize them is usually at the discretion of the highway contractor. TxDOT requires the contractor to gain approval for proposed re-utilization of concrete waste materials; it generally approves proposed re-utilization when the concrete waste material is crushed to approximately 2 inches to be suitable for fill behind headwalls and for incorporation in subbase or base courses.

2.2.1 J. D. Abrams Inc.

One TxDOT highway contractor, J. D. Abrams Inc., currently re-utilizes approximately 50 percent of its concrete waste materials on its projects (R2). Their decision whether or not to re-utilize concrete waste materials is one of economics. When hauling and disposal at a landfill costs less than crushing and re-utilization, they landfill. They operate two rock crushers in Houston, one of which is mobile. Abrams states that it is cost-effective for them to re-utilize concrete waste materials in Houston, but not so in the more rural areas where landfill tipping fees are lower and rock crushers are not available.

2.2.2 The Best Group Inc.

The Best Group Inc., contractor for the demolition of the Texas Rangers' old stadium, states that they will not landfill any of the 50,000 cubic yards of concrete and concrete masonry waste materials (R3). They will haul the waste materials a short distance and deliver it to a storage yard for the city of Arlington, without cost to or compensation from the city, where it will then be processed by the city through a rock crusher for later re-utilization. The arrangement with the city of Arlington is beneficial to both parties. The contractor's cost to dispose of the waste materials is reduced and the city gains a large supply of crushed concrete aggregate materials for its own use. The quantity of structural steel to be salvaged is estimated to be 10,000 tons. Best will receive $125 per ton on site for it, and will also receive $1.00 per pound on site for copper wire. They will also sell the stadium seating and mechanical system components and kitchen/concessionaires equipment. The 120-day contract amount is $450,000. Best states that their profit margin is heavily dependent on revenues and savings realized through the recycling and sale of salvaged materials and equipment.

2.2.3 Clauss Construction

As another specific example, Clauss Construction, a construction contractor in southern California, was awarded a contract that included demolition of concrete/masonry structures and the construction of new facilities. They were able to reduce their bid by 20 percent, primarily by re-utilizing the concrete waste materials from the old structures and incorporating it as a portion of the fill material to support the foundations for the new facilities. In doing so, the contractor saved hauling costs and the purchase costs of gravel he would have otherwise incurred, and also saved landfill tipping fees of $45 per ton. Clauss says they have been "recycling construction debris for several years and that it is becoming a fairly common practice in southern California." The high landfill tipping fees made the re-utilization of the concrete waste materials worthwhile (Naval Facilities Engineering Service Center 1993).

2.3 Potential Applications for the Re-utilization of Concrete Waste Materials

It will become increasingly beneficial to avoid the landfilling of wastes as landfill fees continue to rise, particularly for dense materials such as concrete and steel. Another major cost factor is the transportation of materials.

For a fair comparison, the total costs of landfilling must be compared to the total net costs of re-utilization. When concrete waste materials can be re-utilized for less than they can be disposed of by landfilling, concrete waste materials will be re-utilized.

Applications for the re-utilization of concrete waste materials should include:

- construction of breakwaters and jetties
- shoreline erosion protection surfaces
- lining of drainage channels
- roadbed material
- stabilization and drainage for foundations
- fill for cofferdams and revetments
- construction of gabions
- slope stabilization applications
- surfacing of parking lots and roads
- aggregate for grouting of masonry
- soil erosion prevention applications
- retaining wall backfill
- non-structural concrete (sidewalks)
- manufacture of paver blocks
- french drains/leach fields
- landscaping applications
- hiking trails

3.0 FACTORS PROMOTING THE RE-UTILIZATION OF CONCRETE WASTE MATERIALS

Reducing project costs and limiting environmental impact are foremost concerns of the construction industry. Re-utilization of concrete waste materials is relevant to both of these concerns.

3.1 Immediate Cost-Benefit Considerations

Concrete waste material should be recycled for economic and environmental reasons. As landfilling costs increase, project owners will seek economical means to dispose of construction wastes. In regions where landfill tipping fees are very high, cost considerations have caused the re-utilization of construction waste materials to become more commonplace.

3.2 Relationship to Concept of "Sustainable Development"

"Sustainable development" refers to the promotion of economic growth and technological advancement while maintaining a consciousness of limiting damage to the global environment. Sustainable development is receiving greater emphasis within the construction industry:

> "For economic and related reasons, the use of waste materials in construction as partial or full replacements for conventional geomaterials has increased. As civil engineers, we can

> contribute to sustainable development by optimizing the use of waste materials in construction by striking a balance between economic necessity and mitigation of potential hazards" (Bergeson and Inyang 1992).

As landfilling becomes more costly and less attractive, the cost-effective and environmentally positive use of structural waste will become increasingly important:

> "In order to complete the loop for recycling of solid wastes, uses must be found for waste materials" (Ciesielski and Collins 1992).

Engineers should not narrowly focus their concerns on the construction of structures, but broadly consider the impact on society of construction and the processes and activities that support construction:

> "Sustainable development, which attempts to balance environmental preservation and economic growth, promises a way to provide a decent life for Earth's inhabitants without destroying the global ecosystem. Whether it works will depend a lot on engineers" (Prendergast 1993).

4.0 CURRENT FACTORS INFLUENCING THE VIABILITY OF CONCRETE WASTE MATERIAL RE-UTILIZATION

4.1 Sources of Concrete Waste Materials

Concrete waste materials are produced routinely on construction projects undertaken by both the private and the public sectors. Unexpected and urgent needs for waste disposal are often predicated by seismic events, as after the 1989 Loma Prieta (Prendergast 1994) and the 1994 Northridge (Zelinski 1994) earthquakes. Less urgent disposal of concrete waste materials occurs during the course of a variety of construction projects, including the elective demolition of structures. Many buildings are torn down when they have been determined to be unsound, or when they no longer perform their intended function. Often a structure is removed to make space for some subsequent use. Highway improvement projects often require the removal of concrete pavement sections, culverts, bridges and overpass structures. Military airfield and civilian airport upgrade projects generate concrete waste materials. A single project, the demolition of the Texas Rangers' Arlington Stadium (Tarricone 1994), will require the demolition of over 50,000 cubic yards of reinforced concrete and concrete masonry (R4).

4.2 Factors that Inhibit the Re-utilization of Concrete Waste Materials

In many situations it is impractical to re-utilize concrete waste materials because of the extent to which they are mixed with other items. This would be the case when a building collapses or partially collapses during an earthquake, or it is determined to be unsafe to disassemble the components of a building that is heavily damaged but still standing. Such a structure plus its contents is often brought down by placement of explosive charges and/or the use of a wrecking ball. The ability to effectively re-utilize the structural components is impeded when destructive demolition causes the thorough intermixing of the fragments of the structure with non-structural components such as wall and floor coverings, insulating materials, electrical and mechanical system components, furnishings, etc.

Environmental and safety concerns are often paramount in building demolition situations where asbestos, lead paint, or other materials that require special disposal procedures are present. Clearly, the best way to separate materials would be to methodically disassemble a structure in the approximate reverse of how it was constructed. This would admittedly increase the time and cost to demolish a building. It would be cost-effective to piecewise disassemble a building when the benefits of doing so exceed other alternatives, such as

explosive demolition and landfilling the mixed rubbish. Copper electrical wiring and steel can be salvaged and recycled economically. Mechanical systems can be salvaged or used for parts.

The greatest economy for the re-utilization of concrete waste materials would be from "clean" structures, where the concrete rubble from demolition is not intermixed with other materials. Such would be the case when a building is able to be methodically disassembled, or from structures that are composed mostly of concrete, such as bridges and highway overpasses, parking garages, concrete pavements, and building foundations.

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The recycling of wastes is gaining popularity throughout our society. Protection of the environment from damage and pollution is the laudable objective of environmental activists. However, recycling will achieve universal acceptance only when economics becomes the motivator. Governmental regulations will continue to cause increases in the costs of landfilling, and will continue to be the impetus for consideration of alternatives to landfilling.

According to (Hall and Schaumburg 1994), "recycling is one of the most practical, economically beneficial environmental endeavors people, businesses and local governments have pursued." While it has historically been inexpensive to landfill construction wastes, the option of landfilling construction wastes is becoming less cost-effective as landfill tipping fees are rapidly rising.

5.2 Conclusions

The quantity of concrete waste materials is increasing, and will continue to do so as the quantity of concrete used in construction continues to increase. As landfilling costs rise, it will become economically beneficial for concrete waste materials to be re-utilized. On any given project involving the disposal of

concrete waste materials, the option of landfilling the concrete waste materials should be compared against other options. Tangible considerations will include landfill tipping fees, hauling expenses, the direct costs of rock crushing and other processing, costs avoided by not having to purchase other materials, and revenues generated from the sale of recycled materials. Intangible considerations will include benefits to the environment by reducing the demand to mine construction aggregates and by conserving available landfill space. Sustainable development support will broaden as economic and environmental considerations are balanced. The landfilling of concrete waste materials will stop as engineers and construction managers realize the benefits of doing so. By including concrete as a material that should be re-utilized, our natural resources will be better managed and utilized, and the costs of constructing improvements for society will be minimized.

5.3 Recommendations

Concrete is a material that should not be landfilled. It should not be a single-use disposable material. It will be commonly re-utilized as doing so becomes economically advantageous to landfilling. In both the public and private sectors, the transition from the landfilling of concrete waste materials to the re-utilization of them should take place.

The challenge for engineers and contractors will be to

maximize the advantages of re-utilizing concrete waste materials. This will require consideration of the following factors:

- alternative methods of demolition
- time constraints
- the proximity and availability of rock crushers
- hauling distances and transportation costs
- the supply of and demand for the product
- the pairing of suppliers with consumers of waste products
- streamlining the processes for re-utilization of construction waste materials

The beneficial re-utilization of construction wastes will become increasingly common because of economic and environmental considerations. Entities responsible for the disposal of construction wastes should explore all alternatives to disposal by landfilling. By removing concrete from the solid waste stream, construction costs and environmental impact can be reduced.

6.0 REFERENCES

Ahmed, I. (1992). Use of Waste Materials in Highway Construction. Noyes Data Corp., Park Ridge, NJ, pp. 58 - 61, 82 - 95.

Azis, M. A. and Ramaswamy, S. D. (1992). "Some Waste Materials in Road Construction." Utilization of Waste Materials in Civil Engineering Construction. American Society of Civil Engineers, New York, NY, pp. 153 - 165.

Bergeson, K. L. and Inyang, H. I. (1992). Utilization of Waste Materials in Civil Engineering Construction. American Society of Civil Engineers, New York, NY, pg. iii.

Ciesielski, S. K. and Collins, R. J. (1992). "Highway Construction Use of Wastes and By-Products." Utilization of Wastes Materials in Civil Engineering Construction. American Society of Civil Engineers, New York, NY, pp. 140 - 152.

Hall, J. and Schaumburg, G. W. (1994). "Recycling Efforts Pay Off." Austin American-Statesman, June 13, 1994, pg. A9.

Kesler, S. E. (1994). Mineral Resources, Economics and the Environment. MacMillan Publishing Co., New York, NY, pp. 1 - 6, 287 - 323, 347 - 359.

Kim, K. W., Lee, B. H., Park, J. S. and Doh, Y. S. (1992). "Performance of Crushed Waste Concrete as Aggregate in Structural Concrete." Utilization of Waste Materials in Civil Engineering Construction. American Society of Civil Engineers, New York, NY, pp. 332 - 343.

Naval Facilities Engineering Service Center (1993). "Old Foundation Forms Foundation for New Barracks." Energy and Environmental News, Oct. 1993, pg. 11.

Prendergast, J. (1993). "Engineering Sustainable Development." ASCE Civil Engineering, 63(10) Oct. 1993, pp. 39 - 42.

Prendergast, J. (1994). "Aftershocks: The Legacy of Loma Prieta." ASCE Civil Engineering, 64(1) Jan. 1994, pp. 46 -49.

Suss, G. H. (1989). "Natural and Waste Material - A Chance for Competition?" Unbound Aggregates in Roads. Butterworths, Boston, MA, pp. 219 - 226.

Tarricone, P. (1994). "A League of Their Own." ASCE Civil Engineering, 64(5) May 1994, pp. 58 - 61.

Zelinski, R. (1994). "Road to Recovery." ASCE Civil Engineering, 64(4) Apr. 1994, pp. 36 -39.

Telephone conversations with:

R1: Brown, E. and Dorris, H. Texas Department of Transportation, July 1994.

R2: Keller, R. J. D. Abrams Inc., July 20, 1994.

R3: Nutter, D. and Penton, D. The Best Group Inc., July 1994.

R4: Lyngos, C. The Texas Rangers Baseball Club, July 1, 1994.